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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 17 November 1998 with an application for Letters Patent number 332836 made by FISHER & PAYKEL LTD.

Dated 28 January 2000.

Neville Harris

Neville Harris
Commissioner of Patents

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

NEW ZEALAND

PATENTS ACT, 1953

332836

PROVISIONAL SPECIFICATION

Laundry Machine Improvements

We, FISHER & PAYKEL LIMITED a company duly incorporated under the laws of New Zealand of 78 Springs Road, East Tamaki, Auckland, New Zealand, do hereby declare this invention to be described in the following statement:

INTELLECTUAL PROPERTY OFFICE
OF N.Z.
17 NOV 1998
RECEIVED

This invention relates to laundry machines. In particular it relates to laundry machine drain pump control, power supplies, electronically commutated permanent magnet motor drives and motor braking during spin dry cycles.

Most laundry machine drain pumps use an AC induction motor or synchronous motor, operating off the mains frequency, which is typically 50 or 60Hz. This fixed frequency, along with the mains voltage, determines the design of the pump, and hence the flow rate and maximum head height that can be obtained.

There are numerous disadvantages of a fixed mains-frequency pump motor. These are:

- The starting torque is typically low, making the pump susceptible to being blocked.
- Separate pump designs are needed for the mains voltage and frequency of each country.
- The noise level during "ventilation" is high, particularly when running at a supply frequency of 60Hz.
- The torque varies with the mains voltage.
- There is no feedback to indicate if the pump is faulty.

By the nature of the washing process debris, including strands of textile, is removed from the wash load and flushed into the sump of the washing machine. This debris is then pumped out along with the dirty wash water. Occasionally the pump impeller will catch on the debris, or will start accumulating textile strands and then stop pumping.

These sorts of problems have been solved in other industries like sewage handling, by having powerful motors driving pumps, with large clearances and large flow passages. Home appliances, however, do not have the space available to utilise large flow passages.

One small volume solution in use is the vortex impeller, where the impeller has a shroud around it that eliminates the jamming point between vane end and the 'cutwater'. Unfortunately this pump has the disadvantage that it can still become blocked by bundles of fibres that become twisted "ropes" in the centre of the vortex.

Traditionally a washing machine is turned off by employing one of two methods. In the first power to the washer is isolated using an expensive mains rated switch which de-energises it and makes power consumption negligible. The switch must be capable of carrying and breaking the total current required at the required voltage. In the second method the machine appears to turn off by removing any power indications on its control panel. In reality the machine's power usage would remain indifferent to when it was paused as it is still energised.

These methods have the respective disadvantages that either a high current and/or voltage rated switch is required or power is consumed unnecessarily when the laundry machine is not in use.

A common way of driving an electronically commutated three phase motor is to configure it in an H-Bridge between two dc rails, as shown in figure 5. The six power transistors Q1 to Q6 energise the motor windings by switching in a particular pattern. It is possible to have a high level of control over the speed and torque of the motor if feedback on the position of the rotor is available to the drive circuit logic which controls the switching pattern. The transistors are switched on by applying a voltage, usually 15V, from gate to source. Because the source voltage varies from 0V to the DC rail voltage, some technique is required to get the signal from the driving logic, which is referenced to 0V, to the high side gate which is referenced to the phase output (A, B, and C).

Common techniques are to use pulse transformers, purpose-designed ICs such as the IR2111, or optocouplers. The disadvantage of optocouplers is that conventional drive designs require high quality and therefore high cost devices.

During laundry machine spin dry cycles the spin tub is rotated at relatively high speed. At the termination of the spin cycle it is desirable to brake the motor to minimise spin tub run down speed. Conventionally this has been achieved by connecting resistors across the motor windings. This technique has the disadvantage that relatively high power resistors are required and these add to the cost of the laundry machine.

It is therefore an object of the present invention to provide a laundry machine having drain pump control, a power supply, a motor drive, and a motor braking system which overcomes the respective disadvantages outlined above.

In a first aspect the invention may broadly be said to consist in a washing appliance drain pump characterised in that the pump motor is an ac induction motor driven by a variable frequency inverter.

In a second aspect the invention may broadly be said to consist in a method of controlling a washing appliance drain pump characterised in that the pump is rapidly stopped for a short period of time at periodic intervals.

In a third aspect the invention may broadly be said to consist in a washing machine which is switched on and off using a low current low voltage switch characterised in that the washing machine power supply is a switch mode power supply derived from a drive circuit for an electronically commutated motor and the power supply switch is incorporated in the lower side motor switching transistor drive circuit.

In a fourth aspect the invention may broadly be said to consist in a drive circuit for an electronically commutated motor characterised in that isolation in the drive circuit for the high side switching transistor is achieved by the use of a low quality optocoupler.

In a fifth aspect the invention may broadly be said to consist in a laundry machine having an electronically commutated motor characterised in that said motor is braked regeneratively and the braking energy is dissipated by connecting an inductive component

used for another primary pin power across the dc rails for the motor switching transistors.

This invention may also be said broadly to consist in the parts, elements and features referred to or indicated in the specification of the application, individually or collectively, and any or all combinations of any two or more of said parts, elements or features, and where specific integers are mentioned herein which have known equivalents in the art to which this invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth.

The invention consists in the foregoing and also envisages constructions of which the following gives examples.

Preferred forms of the present invention will now be described with reference to the accompanying drawings in which;

Figure 1 shows a plan view of a laundry machine sludge pump,

Figure 2 shows a sludge impeller with a vortex impeller,

Figure 3 shows a voltage waveform for a laundry machine sludge pump controlled in accordance with the present invention,

Figure 4 shows a circuit for a laundry machine power supply derived from the laundry machine motor drive,

Figure 5 shows a totem pole switching circuit for a three phase motor drive,

Figure 6 shows a high side drive circuit using an optocoupler for the circuit of Figure 5,

Figure 7 shows a high side optocoupler drive circuit according to the present invention, and

Figure 8 shows a braking circuit for a laundry machine motor.

Variable Speed Induction Motor Drain Pump

The laundry machine drain pump of the present invention uses four switching devices in an "H-bridge" configuration (of the type shown in Figure 4) to switch a 230V / 50Hz AC induction motor drain pump off a 325V DC rail (peak valve of 230 volt RMS mains vontage), under the control of a microprocessor. This allows the frequency and RMS voltage being applied to the pump to be controlled. The switching signals are pulse width modulated with a variable duty cycle..

Variable Speed Pumping during drain

When the water level is above a predetermined height - the "bowl float level" in a machine of the type described in New Zealand patent 215389/217623/218356 - the pump speed is set to 60Hz, to maximise the flow rate. When it is below this level, "ventilation"

will occur, so the pump speed is reduced to 50Hz. This reduces the noise level dramatically, but still maintains the ability to pump over an acceptable head height.

Variable speed pumping has three main advantages over fixed speed pumps:

- The drain time at 60Hz is approximately 15% less than at 50Hz, due to the higher flow rate. This reduces a typical cycle time by about 1-2 minutes.
- Audible noise is greatly reduced during "ventilation", since we slow the pump to 50Hz.
- We can use the same 230VAC / 50Hz pump design for all countries.

Low frequency, high torque pump startup

(a) "Kickstart"

The starting torque of an AC induction motor increases when the supply frequency is decreased. In this invention, when the pump starts, the drain pump microprocessor switches it at 30Hz, with an increased duty cycle, for the first 4 revolutions (ie. 80ms at 50Hz). This provides a high torque "kick", which will attempt to dislodge anything which is impeding the pump impeller.

(b) "Startup"

The pump then changes to the target frequency (50 or 60Hz), but with a high duty cycle, for the next 150 revolutions (3 seconds at 50Hz). This helps to initially get the water over the required head height.

After the "kickstart" and "startup" stages, the pump changes to the "normal" duty cycle for the desired frequency.

By intelligently controlling the frequency and duty cycle during pump startup, a reduction in pump blockage can be achieved.

Variable pump PWM depending on mains voltage

The AC mains voltage has a typical tolerance of 10%, which for nominal 230V AC, equates to a range of 207V AC to 253V AC. In rural areas, this variation can be even greater. This mains voltage variation has an effect on the torque of the drain pump, and hence on the maximum head height and flow rate.

In this invention, the microprocessor also measures the DC rail voltage, and hence the mains voltage can be determined. Mains voltage variation is compensated by adjusting the duty cycle of the drive signal to the pump. If the AC mains voltage drops, the duty cycle is increased, and vice versa, thereby maintaining a constant torque in the drain pump over a wide range of mains conditions.

A secondary feature is related to the fact that when driving the pump at 60Hz, the maximum torque available is less than when driving at 50Hz. If the pump is operating at 60Hz, and the mains voltage drops below a predetermined level (200V for nominal 230V), the flow rate will drop to an unacceptable level. Therefore the pump motor frequency is reduced to 50Hz, and 60Hz operation disabled until the hardware is reset.

By using variable duty cycle that is a function of mains voltage, a constant drain pump performance is maintained over a wider range of mains voltages than is normally possible. Secondly, by disabling the 60Hz mode of operation when the mains drops below a predetermined voltage, the problem of very low flow rates is avoided when attempting to drain at 60Hz under low mains conditions.

Pump Over-current Detection

Washing machine drain pumps are susceptible to water damage if they leak. This water damage eventually causes electrical shorting of the pump windings increasing the winding current and causing it to overheat and fail, due to the change in winding resistance and inductance characteristics. As well as being a potential fire/smoke risk, this overheating and failure can also damage the hardware that is driving the pump, unless additional protection is provided.

Conventionally, there is no feedback indicative of current in the pump windings, so there is no "early warning" that the pump is being damaged in such circumstances. In the present invention the current peaks in the pump windings are monitored. The current may typically peak at approximately 1.1A (rms = 650mA). If the microprocessor detects two consecutive current peaks of greater than 2.6A, it flags a "pump overcurrent" fault to the motor controller microprocessor.

Since the change in electrical characteristics from water damage is gradual, this fault condition will occur before any other parts of the circuit are damaged, and before the pump becomes a potential fire/smoke hazard. It allows the replacement of a water-damaged pump before any other subsequent damage occurs.

Pump stopping to clear lint and thus prevent pump blocks

In a second embodiment of this invention there is provided a means of drain pump motor control that will flush through bundles of fibres before they become large enough to jam the pump. Typically the pump motor will be an ac induction motor which may be of the shaded pole type.

This goal is achieved by stopping the pump very quickly for a short period of time every few seconds. The sudden stop of the pump means that there is no more energy put into the vortex, and the momentum of the water flowing down the discharge pipe sucks

A typical prior art circuit which employs an optocoupler for driving the high side transistor is shown in Figure 6. When Q2 switches off, noise is generated which tends to pull the optocoupler off. In Figure 6 there is a logic inversion via q4 which ensures that turn off to the optocoupler means turn off of Q1. Given that Q1 should always be off during turn off of Q2, correct operation of the circuit is not compromised.

The present invention provides a more cost effective circuit as shown in Figure 7. In this configuration, turn off of Q2 tends to turn on Q1. Resistor R is selected to limit the turn on speed of Q1 so there is no risk of overlap. Because this causes a slewed turn on for Q1, this circuit is only appropriate for switching Q1 at low frequency. Therefore the motor must be energised at audible switching frequencies.

The octocoupler can have relatively low gain and slew rate, which allows the use of a more cost effective device. There is also no need for q4 (see Figure 6).

Configuring at least one high side drive as in Figure 7 is necessary to facilitate the power supply ON-OFF concept described in relation to Figure 4.

Braking the Wash Tub Motor

In a fifth embodiment the invention provides a low cost method of braking a laundry machine motor.

One of the functions of a top loading vertical axis washing machine is to spin the wash tub at high rpm to remove excess water from the clothes at the end of the wash cycle. A spinning tub is unsafe for a user to touch so many machines have a brake function that quickly stops the spinning tub if the lid is opened. This brake function can be done by different techniques and one technique that is becoming more common is to use regenerative braking from the main drive motor. Using this technique the drive motor effectively acts as a generator during brake and converts the energy from the spinning tub into electrical energy which is typically then converted into heat and dissipated via a dump resistor.

The present invention places an already existing motor or solenoid across the DC voltage rails for the motor so that the electrical energy generated during braking of the spinning tub can be dissipated in this motor/solenoid impedance saving the cost of additional components needed for a dump resistor or equivalent.

The circuit shown in Figure 8 has a 3 phase brushless DC main motor for driving a laundry machine agitator and or spin tub and an AC induction motor water pump driven from the HVDC bus via a transistor H bridge. When the main motor is driven as a generator, during a brake phase, electrical energy is fed back into the HVDC bus which

the vortex and any fibres entrapped in the vortex out the pump exit. The pump is started again before the velocity in the discharge pipe reduces to zero so that the trapped fibres carry on out into the drain. If the pump off time is too long the discharge flow will stop and then reverses returning the fibres to the pump.

To achieve the sudden stop, a direct current is applied to the shaded pole (asynchronous) motor for 200mS. This current produces a stationary flux that acts as a brake. It has been found experimentally that a stop for 200mS every 10 seconds gives the best results.

In one embodiment of this invention the shaded pole motor has half wave rectified voltage applied to produce the stationary flux.

Figure 1 shows the plan view of a laundry machine sludge pump, with the impeller 1 having two, backwardly inclined vanes 2, 3, with large clearances, especially to the cutwater 4. Figure 2 shows a perspective view of a sludge impeller 1 with a vortex impeller 5 with the vanes recessed into the impeller. Figure 3 shows the voltage history of the half wave rectified version, with interval 6 the first 200mS stop interval, then a ten second (full wave) pumping period, 7 followed by a second 200mS stop period 8.

Power Supply ON-OFF

In a third embodiment the invention provides a means of allowing a laundry machine power supply to power down automatically and power up via a low voltage, low current switch. This eliminates the need for a high current and/or voltage rated switch and ensures negligible power consumption when the laundry machine is not in use.

Referring to Figure 4 power supply for the machine is produced by employing a simple switch mode power supply (SMPS) topology that is controlled by a microprocessor and makes use of the motor windings and motor drive circuit. This general form of laundry machine power supply is described in New Zealand Patent 236551. The power supply is disabled by a hardware circuit (fourth wire circuit). Power down functions are initiated by the micro processor and locked by the fourth wire circuit. Power up functions are initiated by the user via a low voltage, low current push button.

- Power down

When the machine has finished a task and has received no further instructions for some defined time period, the microprocessor simply reduces the power output of the SMPS to zero hence powering down the product. The fourth wire circuit is then enabled to ensure the SMPS does not power up until the user presses the appropriate push button on the control panel. This dramatically reduces the power consumption of the machine compared to that required by the hardware lockout circuitry.

- Power up

The user presses a power button which disables the fourth wire circuit that is disabling the SMPS. The SMPS then starts up and brings alive the microprocessors. The machine is now ready for use.

For example, Figure 4 shows the simplified schematic of a motor power supply as described in New Zealand Patent 236551. In this design a buck converter is inherent in the H-bridge topology of the motor drive. Assume that A+ and B- devices are off when the circuit is run as a buck converter, then A- is latched on and B+ is driven by a PWM signal to control power output. The circuit can be modified by adding the "hardware lock off" circuitry to provide shutdown and start up functions.

- Power down

To shut down the SMPS the microprocessor simply turns off A- by turning on Tx2. The 15v rail (produced by the SMPS) will drop and Tx1 previously biased on by the 15v will turn off allowing C1 to charge. C1 then latches Tx2 on hard so that A- is latched off. Thus the buck converter is disabled.

- Power Up

The user presses Sw1 which discharges C1 thus turning off Tx2 allowing A- to turn on. The SMPS is then able to start up and produce the 15v rail required to latch Tx1 on. The product is now ready for use.

The employment of the aforementioned hardware/microprocessor controlled SMPS has the following advantages:

- A cheap low current, low voltage switch to be used to provide power up functions.
- The power switch can be referenced to the SMPS zero volt rail allowing it to be used for other functions.
- Allowing the SMPS to shut down extends the life time of components and reduces any emissions from the product (i.e. RFI, EMI).
- Provides very low power consumption when not in use.
- Eliminates transients caused by mains power interruption.

ECM Motor Drive

In a fourth embodiment the present invention provides a low cost high side drive for an H bridge switching circuit for an electronically commutated motor. Such a switching circuit is shown in Figure 5.

results in an increase in the bus voltage. When the bus voltage exceeds 400V DC, transistors A+ and B- of the pump H bridge turn hard on and stay on until the bus voltage falls below 390V. In this way energy is dissipated as heat in the pump windings. This heat is dissipated in the pump as power according to the equation:

$$P_{pump} = I^2_{pump} \times R_{pump} \dots\dots\dots (1)$$

The pump has a resistance of approximately 34 ohms. Therefor for a braking power of say 600W, from equation 1, I is around 4.2 amps.

The following advantages are achieved by this embodiment of the present invention:

1) A dump resistor and control circuit are eliminated.
2) By turning the pump on after a braking phase the braking energy (heat) is quickly dissipated by the pump fan.
3) The heat rise due to the energy (heat) being dissipated in the pump windings is remote to the enclosed electronics area where it is difficult to ventilate and hence cool.
4) Winding inductance reduces the peak currents that would flow in a similar load, and hence control transistors, that was substantially only resistive.

It should be apprecaited that other existing laundry machine resistive/inductive components could be utilised in place of the drain pump motor as a means of dissipating power. For example the solenoid is a solenoid controlled valve or other actuator could be used.

DATED THIS 17th DAY OF November 1998
A.J. PARK & SON
PER Tabatha O'Leary
AGENTS FOR THE APPLICANT

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There are numerous disadvantages of a fixed mains-frequency pump motor. These are:

- The starting torque is typically low, making the pump susceptible to being blocked.
- Separate pump designs are needed for the mains voltage and frequency of each country.
- The noise level during "ventilation" is high, particularly when running at a supply frequency of 60Hz.
- The torque varies with the mains voltage.
- There is no feedback to indicate if the pump is faulty.

By the nature of the washing process debris, including strands of textile, is removed from the wash load and flushed into the sump of the washing machine. This debris is then pumped out along with the dirty wash water. Occasionally the pump impeller will catch on the debris, or will start accumulating textile strands and then stop pumping.

These sorts of problems have been solved in other industries like sewage handling, by having powerful motors driving pumps, with large clearances and large flow passages. Home appliances, however, do not have the space available to utilise large flow passages.

One small volume solution in use is the vortex impeller, where the impeller has a shroud around it that eliminates the jamming point between vane end and the 'cutwater'. Unfortunately this pump has the disadvantage that it can still become blocked by bundles of fibres that become twisted "ropes" in the centre of the vortex.

Traditionally a washing machine is turned off by employing one of two methods. In the first power to the washer is isolated using an expensive mains rated switch which de-energises it and makes power consumption negligible. The switch must be capable of carrying and breaking the total current required at the required voltage. In the second method the machine appears to turn off by removing any power indications on its control panel. In reality the machine's power usage would remain indifferent to when it was paused as it is still energised.

These methods have the respective disadvantages that either a high current and/or voltage rated switch is required or power is consumed unnecessarily when the laundry machine is not in use.

A common way of driving an electronically commutated three phase motor is to configure it in an H-Bridge between two dc rails, as shown in figure 5. The six power transistors Q1 to Q6 energise the motor windings by switching in a particular pattern. It is possible to have a high level of control over the speed and torque of the motor if feedback on the position of the rotor is available to the drive circuit logic which controls the switching pattern. The transistors are switched on by applying a voltage, usually 15V, from gate to source. Because the source voltage varies from 0V to the DC rail voltage, some technique is required to get the signal from the driving logic, which is referenced to 0V, to the high side gate which is referenced to the phase output (A, B, and C).

Common techniques are to use pulse transformers, purpose-designed ICs such as the IR2111, or optocouplers. The disadvantage of optocouplers is that conventional drive designs require high quality and therefore high cost devices.

During laundry machine spin dry cycles the spin tub is rotated at relatively high speed. At the termination of the spin cycle it is desirable to brake the motor to minimise spin tub run down speed. Conventionally this has been achieved by connecting resistors across the motor windings. This technique has the disadvantage that relatively high power resistors are required and these add to the cost of the laundry machine.

It is therefore an object of the present invention to provide a laundry machine having drain pump control, a power supply, a motor drive, and a motor braking system which overcomes the respective disadvantages outlined above.

In a first aspect the invention may broadly be said to consist in a washing appliance drain pump characterised in that the pump motor is an ac induction motor driven by a variable frequency inverter.

In a second aspect the invention may broadly be said to consist in a method of controlling a washing appliance drain pump characterised in that the pump is rapidly stopped for a short period of time at periodic intervals.

In a third aspect the invention may broadly be said to consist in a washing machine which is switched on and off using a low current low voltage switch characterised in that the washing machine power supply is a switch mode power supply derived from a drive circuit for an electronically commutated motor and the power supply switch is incorporated in the lower side motor switching transistor drive circuit.

In a fourth aspect the invention may broadly be said to consist in a drive circuit for an electronically commutated motor characterised in that isolation in the drive circuit for the high side switching transistor is achieved by the use of a low quality optocoupler.

In a fifth aspect the invention may broadly be said to consist in a laundry machine having an electronically commutated motor characterised in that said motor is braked regeneratively and the braking energy is dissipated by connecting an inductive component

used for another primary pin power across the dc rails for the motor switching transistors.

This invention may also be said broadly to consist in the parts, elements and features referred to or indicated in the specification of the application, individually or collectively, and any or all combinations of any two or more of said parts, elements or features, and where specific integers are mentioned herein which have known equivalents in the art to which this invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth.

The invention consists in the foregoing and also envisages constructions of which the following gives examples.

Preferred forms of the present invention will now be described with reference to the accompanying drawings in which;

Figure 1 shows a plan view of a laundry machine sludge pump,

Figure 2 shows a sludge impeller with a vortex impeller,

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Figure 6 shows a high side drive circuit using an optocoupler for the circuit of Figure 5,

Figure 7 shows a high side optocoupler drive circuit according to the present invention, and

Figure 8 shows a braking circuit for a laundry machine motor.

Variable Speed Induction Motor Drain Pump

The laundry machine drain pump of the present invention uses four switching devices in an "H-bridge" configuration (of the type shown in Figure 4) to switch a 230V / 50Hz AC induction motor drain pump off a 325V DC rail (peak valve of 230 volt RMS mains vontage), under the control of a microprocessor. This allows the frequency and RMS voltage being applied to the pump to be controlled. The switching signals are pulse width modulated with a variable duty cycle..

Variable Speed Pumping during drain

When the water level is above a predetermined height - the "bowl float level" in a machine of the type described in New Zealand patent 215389/217623/218356 - the pump speed is set to 60Hz, to maximise the flow rate. When it is below this level, "ventilation"

will occur, so the pump speed is reduced to 50Hz. This reduces the noise level dramatically, but still maintains the ability to pump over an acceptable head height.

Variable speed pumping has three main advantages over fixed speed pumps:

- The drain time at 60Hz is approximately 15% less than at 50Hz, due to the higher flow rate. This reduces a typical cycle time by about 1-2 minutes.
- Audible noise is greatly reduced during "ventilation", since we slow the pump to 50Hz.
- We can use the same 230VAC / 50Hz pump design for all countries.

Low frequency, high torque pump startup

(a) "Kickstart"

The starting torque of an AC induction motor increases when the supply frequency is decreased. In this invention, when the pump starts, the drain pump microprocessor switches it at 30Hz, with an increased duty cycle, for the first 4 revolutions (ie. 80ms at 50Hz). This provides a high torque "kick", which will attempt to dislodge anything which is impeding the pump impeller.

(b) "Startup"

The pump then changes to the target frequency (50 or 60Hz), but with a high duty cycle, for the next 150 revolutions (3 seconds at 50Hz). This helps to initially get the water over the required head height.

After the "kickstart" and "startup" stages, the pump changes to the "normal" duty cycle for the desired frequency.

By intelligently controlling the frequency and duty cycle during pump startup, a reduction in pump blockage can be achieved.

Variable pump PWM depending on mains voltage

The AC mains voltage has a typical tolerance of 10%, which for nominal 230V AC, equates to a range of 207V AC to 253V AC. In rural areas, this variation can be even greater. This mains voltage variation has an effect on the torque of the drain pump, and hence on the maximum head height and flow rate.

In this invention, the microprocessor also measures the DC rail voltage, and hence the mains voltage can be determined. Mains voltage variation is compensated by adjusting the duty cycle of the drive signal to the pump. If the AC mains voltage drops, the duty cycle is increased, and vice versa, thereby maintaining a constant torque in the drain pump over a wide range of mains conditions.

A secondary feature is related to the fact that when driving the pump at 60Hz, the maximum torque available is less than when driving at 50Hz. If the pump is operating at 60Hz, and the mains voltage drops below a predetermined level (200V for nominal 230V), the flow rate will drop to an unacceptable level. Therefore the pump motor frequency is reduced to 50Hz, and 60Hz operation disabled until the hardware is reset.

By using variable duty cycle that is a function of mains voltage, a constant drain pump performance is maintained over a wider range of mains voltages than is normally possible. Secondly, by disabling the 60Hz mode of operation when the mains drops below a predetermined voltage, the problem of very low flow rates is avoided when attempting to drain at 60Hz under low mains conditions.

Pump Over-current Detection

Washing machine drain pumps are susceptible to water damage if they leak. This water damage eventually causes electrical shorting of the pump windings increasing the winding current and causing it to overheat and fail, due to the change in winding resistance and inductance characteristics. As well as being a potential fire/smoke risk, this overheating and failure can also damage the hardware that is driving the pump, unless additional protection is provided.

Conventionally, there is no feedback indicative of current in the pump windings, so there is no "early warning" that the pump is being damaged in such circumstances. In the present invention the current peaks in the pump windings are monitored. The current may typically peak at approximately 1.1A (rms = 650mA). If the microprocessor detects two consecutive current peaks of greater than 2.6A, it flags a "pump overcurrent" fault to the motor controller microprocessor.

Since the change in electrical characteristics from water damage is gradual, this fault condition will occur before any other parts of the circuit are damaged, and before the pump becomes a potential fire/smoke hazard. It allows the replacement of a water-damaged pump before any other subsequent damage occurs.

Pump stopping to clear lint and thus prevent pump blocks

In a second embodiment of this invention there is provided a means of drain pump motor control that will flush through bundles of fibres before they become large enough to jam the pump. Typically the pump motor will be an ac induction motor which may be of the shaded pole type.

This goal is achieved by stopping the pump very quickly for a short period of time every few seconds. The sudden stop of the pump means that there is no more energy put into the vortex, and the momentum of the water flowing down the discharge pipe sucks

the vortex and any fibres entrapped in the vortex out the pump exit. The pump is started again before the velocity in the discharge pipe reduces to zero so that the trapped fibres carry on out into the drain. If the pump off time is too long the discharge flow will stop and then reverses returning the fibres to the pump.

To achieve the sudden stop, a direct current is applied to the shaded pole (asynchronous) motor for 200mS. This current produces a stationary flux that acts as a brake. It has been found experimentally that a stop for 200mS every 10 seconds gives the best results.

In one embodiment of this invention the shaded pole motor has half wave rectified voltage applied to produce the stationary flux.

Figure 1 shows the plan view of a laundry machine sludge pump, with the impeller 1 having two, backwardly inclined vanes 2, 3, with large clearances, especially to the cutwater 4. Figure 2 shows a perspective view of a sludge impeller 1 with a vortex impeller 5 with the vanes recessed into the impeller. Figure 3 shows the voltage history of the half wave rectified version, with interval 6 the first 200mS stop interval, then a ten second (full wave) pumping period, 7 followed by a second 200mS stop period 8.

Power Supply ON-OFF

In a third embodiment the invention provides a means of allowing a laundry machine power supply to power down automatically and power up via a low voltage, low current switch. This eliminates the need for a high current and/or voltage rated switch and ensures negligible power consumption when the laundry machine is not in use.

Referring to Figure 4 power supply for the machine is produced by employing a simple switch mode power supply (SMPS) topology that is controlled by a microprocessor and makes use of the motor windings and motor drive circuit. This general form of laundry machine power supply is described in New Zealand Patent 236551. The power supply is disabled by a hardware circuit (fourth wire circuit). Power down functions are initiated by the micro processor and locked by the fourth wire circuit. Power up functions are initiated by the user via a low voltage, low current push button.

- Power down

When the machine has finished a task and has received no further instructions for some defined time period, the microprocessor simply reduces the power output of the SMPS to zero hence powering down the product. The fourth wire circuit is then enabled to ensure the SMPS does not power up until the user presses the appropriate push button on the control panel. This dramatically reduces the power consumption of the machine compared to that required by the hardware lockout circuitry.

- Power up

The user presses a power button which disables the fourth wire circuit that is disabling the SMPS. The SMPS then starts up and brings alive the microprocessors. The machine is now ready for use.

For example, Figure 4 shows the simplified schematic of a motor power supply as described in New Zealand Patent 236551. In this design a buck converter is inherent in the H-bridge topology of the motor drive. Assume that A+ and B- devices are off when the circuit is run as a buck converter, then A- is latched on and B+ is driven by a PWM signal to control power output. The circuit can be modified by adding the "hardware lock off" circuitry to provide shutdown and start up functions.

- Power down

To shut down the SMPS the microprocessor simply turns off A- by turning on Tx2. The 15v rail (produced by the SMPS) will drop and Tx1 previously biased on by the 15v will turn off allowing C1 to charge. C1 then latches Tx2 on hard so that A- is latched off. Thus the buck converter is disabled.

- Power Up

The user presses Sw1 which discharges C1 thus turning off Tx2 allowing A- to turn on. The SMPS is then able to start up and produce the 15v rail required to latch Tx1 on. The product is now ready for use.

The employment of the aforementioned hardware/microprocessor controlled SMPS has the following advantages:

- A cheap low current, low voltage switch to be used to provide power up functions.
- The power switch can be referenced to the SMPS zero volt rail allowing it to be used for other functions.
- Allowing the SMPS to shut down extends the life time of components and reduces any emissions from the product (i.e. RFI, EMI).
- Provides very low power consumption when not in use.
- Eliminates transients caused by mains power interruption.

ECM Motor Drive

In a fourth embodiment the present invention provides a low cost high side drive for an H bridge switching circuit for an electronically commutated motor. Such a switching circuit is shown in Figure 5.

A typical prior art circuit which employs an optocoupler for driving the high side transistor is shown in Figure 6. When Q2 switches off, noise is generated which tends to pull the optocoupler off. In Figure 6 there is a logic inversion via q4 which ensures that turn off to the optocoupler means turn off of Q1. Given that Q1 should always be off during turn off of Q2, correct operation of the circuit is not compromised.

The present invention provides a more cost effective circuit as shown in Figure 7. In this configuration, turn off of Q2 tends to turn on Q1. Resistor R is selected to limit the turn on speed of Q1 so there is no risk of overlap. Because this causes a slewed turn on for Q1, this circuit is only appropriate for switching Q1 at low frequency. Therefore the motor must be energised at audible switching frequencies.

The octocoupler can have relatively low gain and slew rate, which allows the use of a more cost effective device. There is also no need for q4 (see Figure 6).

Configuring at least one high side drive as in Figure 7 is necessary to facilitate the power supply ON-OFF concept described in relation to Figure 4.

Braking the Wash Tub Motor

In a fifth embodiment the invention provides a low cost method of braking a laundry machine motor.

One of the functions of a top loading vertical axis washing machine is to spin the wash tub at high rpm to remove excess water from the clothes at the end of the wash cycle. A spinning tub is unsafe for a user to touch so many machines have a brake function that quickly stops the spinning tub if the lid is opened. This brake function can be done by different techniques and one technique that is becoming more common is to use regenerative braking from the main drive motor. Using this technique the drive motor effectively acts as a generator during brake and converts the energy from the spinning tub into electrical energy which is typically then converted into heat and dissipated via a dump resistor.

The present invention places an already existing motor or solenoid across the DC voltage rails for the motor so that the electrical energy generated during braking of the spinning tub can be dissipated in this motor/solenoid impedance saving the cost of additional components needed for a dump resistor or equivalent.

The circuit shown in Figure 8 has a 3 phase brushless DC main motor for driving a laundry machine agitator and or spin tub and an AC induction motor water pump driven from the HVDC bus via a transistor H bridge. When the main motor is driven as a generator, during a brake phase, electrical energy is fed back into the HVDC bus which

results in an increase in the bus voltage. When the bus voltage exceeds 400V DC, transistors A+ and B- of the pump H bridge turn hard on and stay on until the bus voltage falls below 390V. In this way energy is dissipated as heat in the pump windings. This heat is dissipated in the pump as power according to the equation:

$$P_{pump} = I^2_{pump} X R_{pump} \ldots\ldots\ldots (1)$$

The pump has a resistance of approximately 34 ohms. Therefor for a braking power of say 600W, from equation 1, I is around 4.2 amps.

The following advantages are achieved by this embodiment of the present invention:

1) A dump resistor and control circuit are eliminated.
2) By turning the pump on after a braking phase the braking energy (heat) is quickly dissipated by the pump fan.
3) The heat rise due to the energy (heat) being dissipated in the pump windings is remote to the enclosed electronics area where it is difficult to ventilate and hence cool.
4) Winding inductance reduces the peak currents that would flow in a similar load, and hence control transistors, that was substantially only resistive.

It should be apprecaited that other existing laundry machine resistive/inductive components could be utilised in place of the drain pump motor as a means of dissipating power. For example the solenoid is a solenoid controlled valve or other actuator could be used.

DATED THIS 17th DAY OF November 1998
A.J. PARK & SON
PER Tabatha O'Leary
AGENTS FOR THE APPLICANT

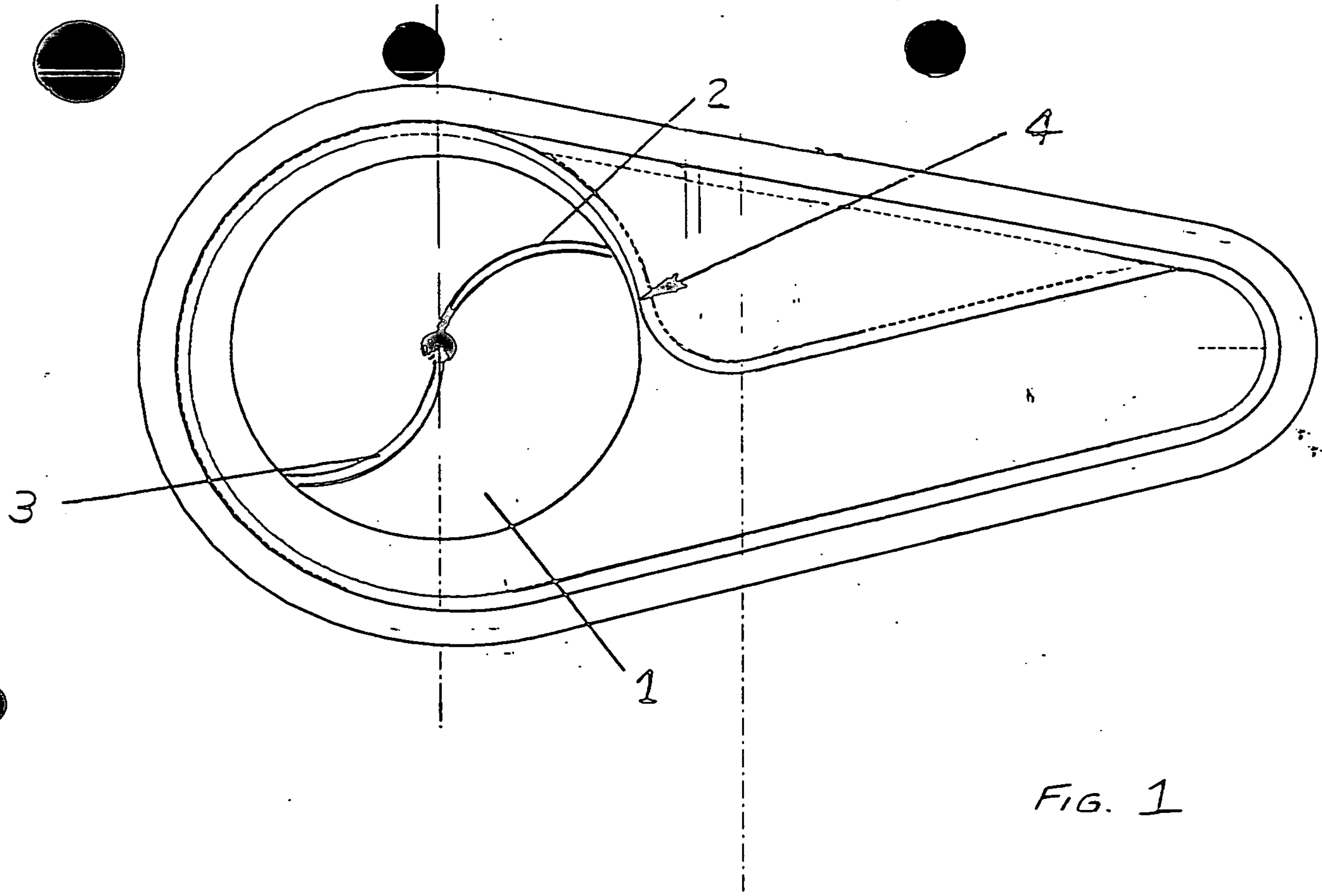


FIG. 1

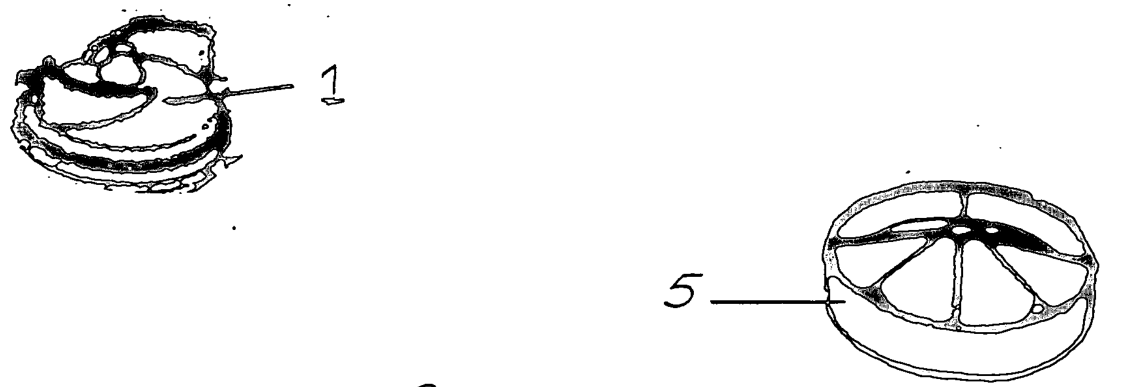
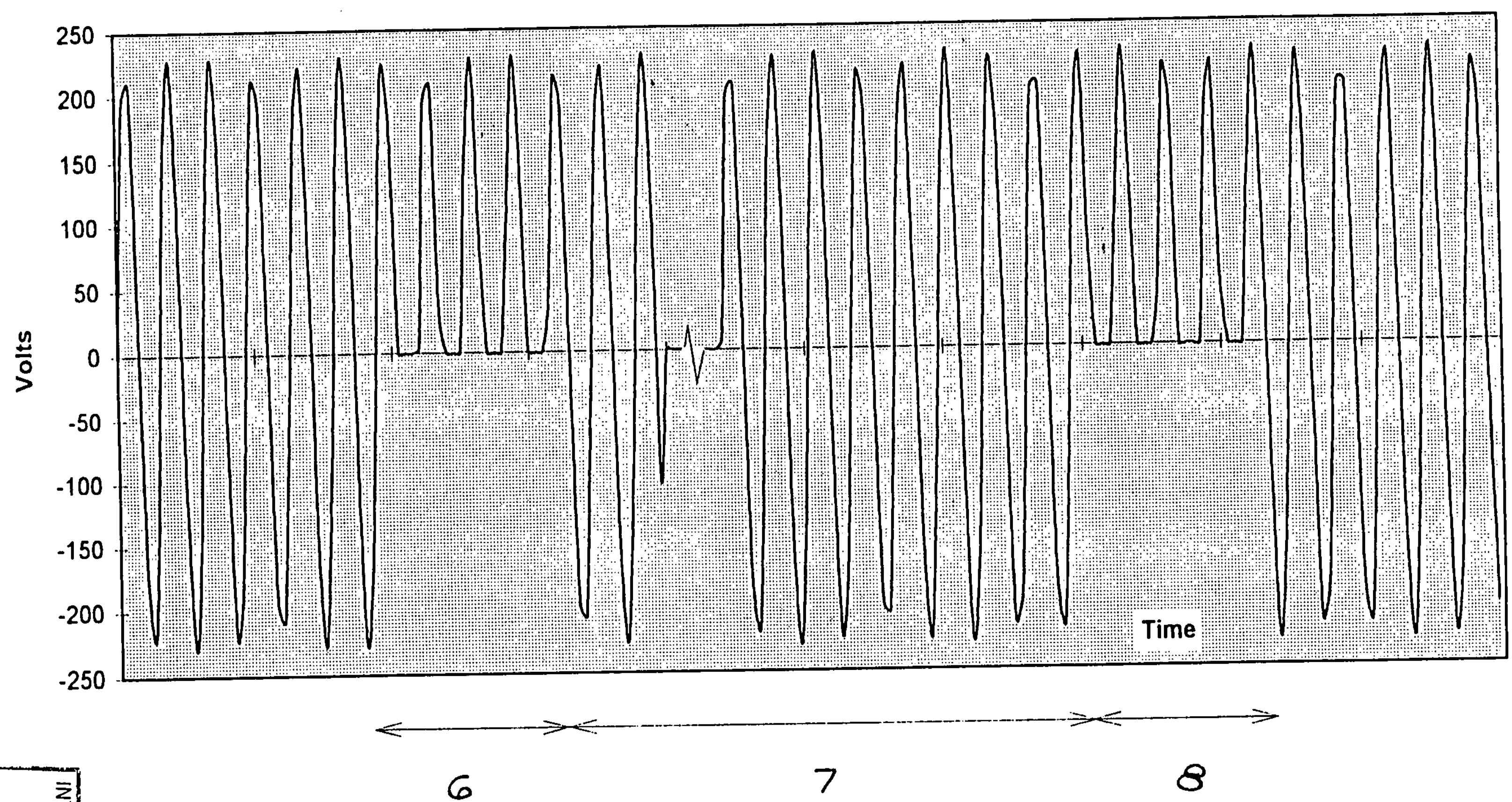
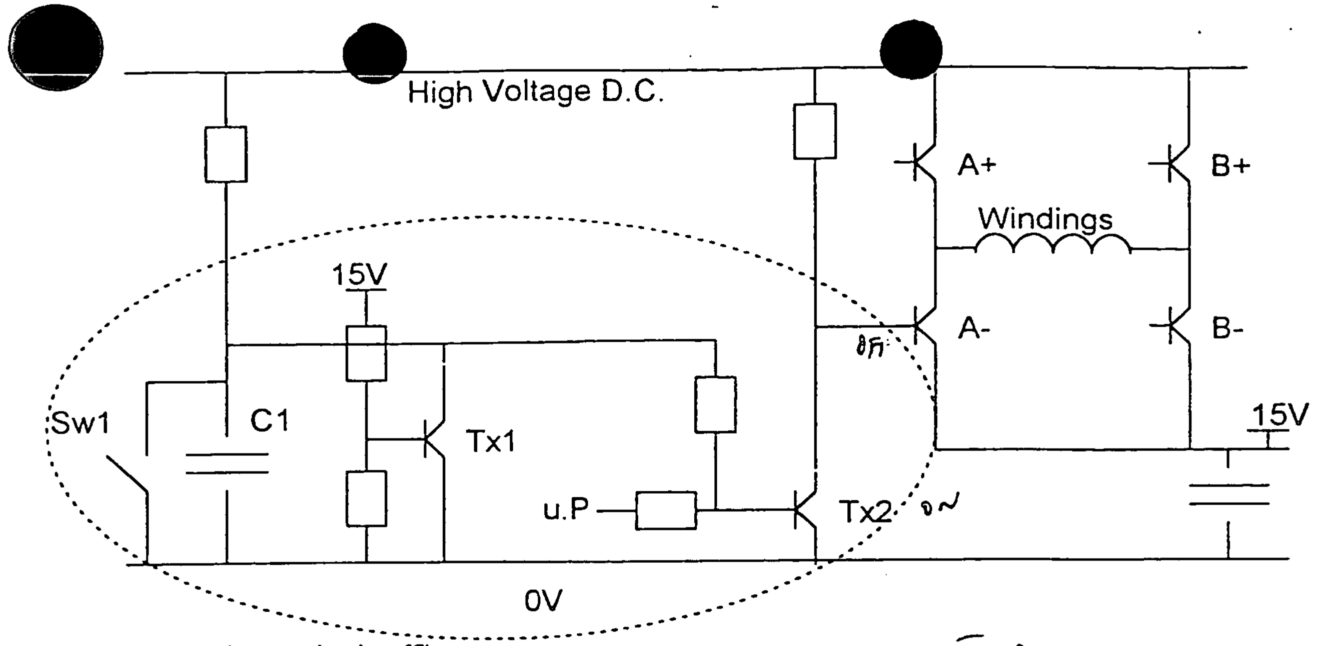


FIG 2

FIGURE 3:Voltage Profile

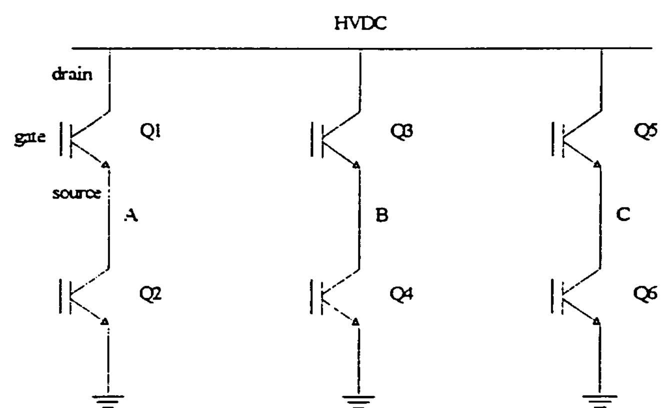




"Hardware lock off"

FIG 4

[redacted] Buck converter example



[redacted]**Totem pole circuit used to drive a three phase**

FIG 5

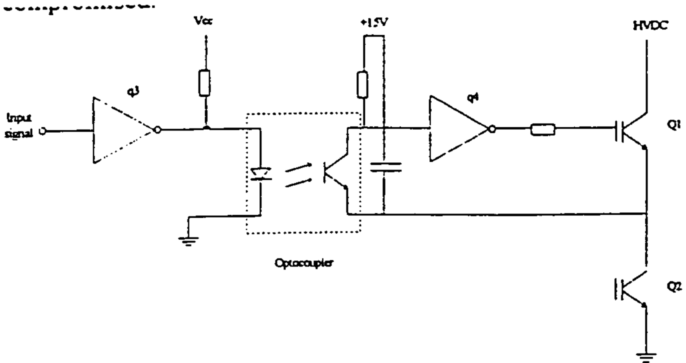


FIG 6

[redacted] Typical high side drive employing an optocoupler. Adapted from HP Designer's Guide to Isolation Circuits, 1995

Concept

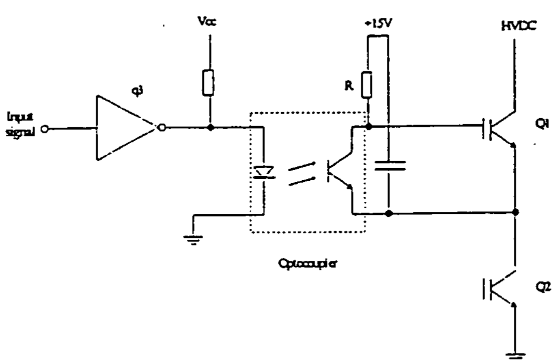


FIG 7

[redacted] More cost effective circuit. Turning on the optocoupler turns off Q1.

Motor as a brake resistor.

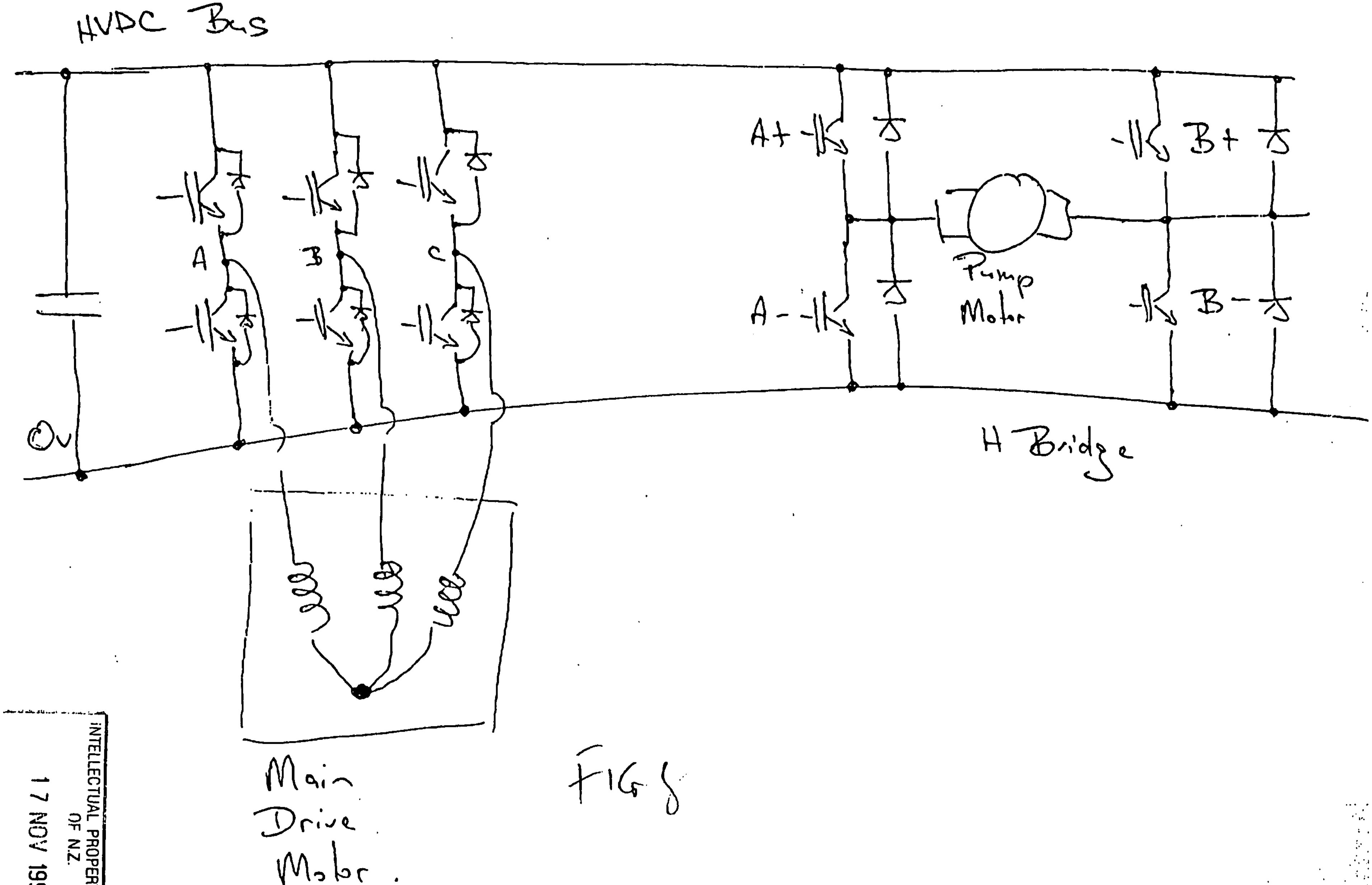


FIG 8

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